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Evaluation strategies in CT scanning

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Evaluation strategies in CT scanning – A case study

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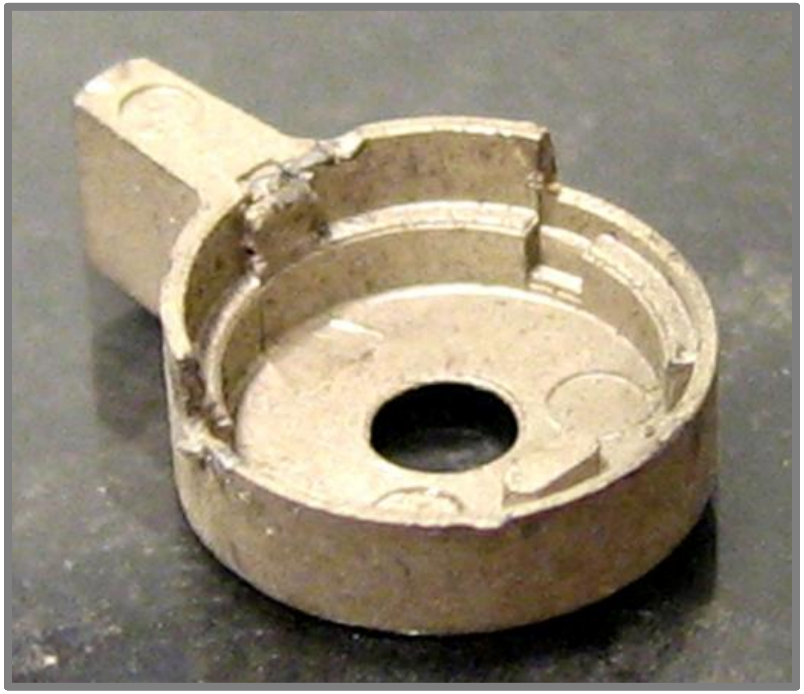
DTU Mechanical Engineering
Department of Mechanical Engineering

Overview

- Motivation
- Objectives and description of a performed case study
- Measuring setup for tactile, optical and CT measurements
- Uncertainty assessment
- Definition of measuring strategies
- Results
- Conclusions

Motivation

Sample

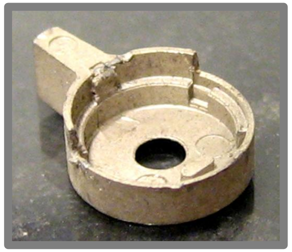


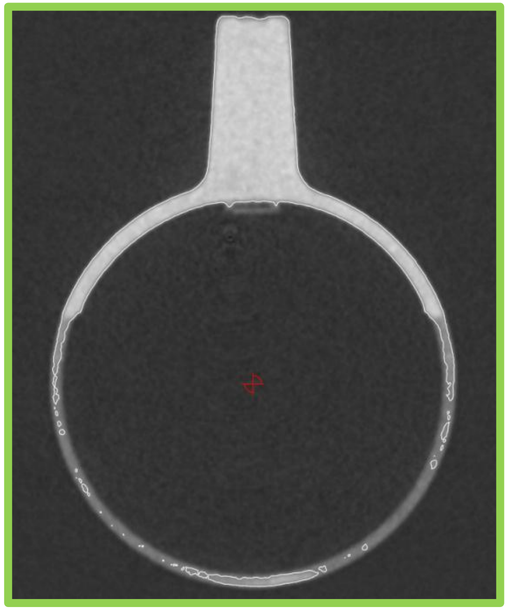
Motivation

CT data recording

Motivation

CT data recording → Volume / voxel data





Motivation

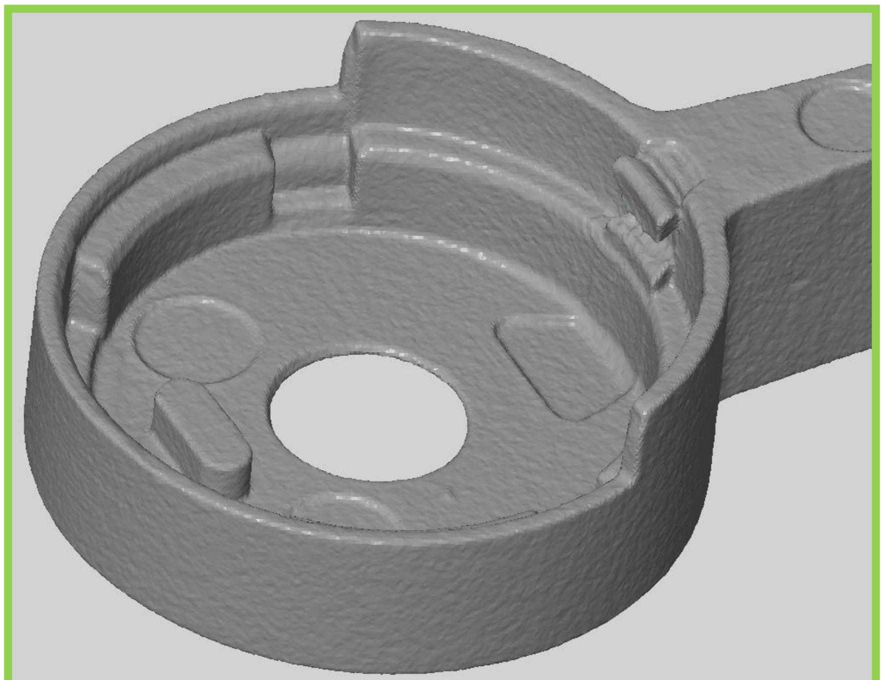
CT data recording → Volume / voxel data → Surface determination

Motivation

CT data recording → Volume / voxel data → Surface determination

→ Volume data

→ Surface data / STL



Motivation

CT data recording → Volume / voxel data → Surface determination

Surface determination → Volume data

Surface determination → Surface data / STL

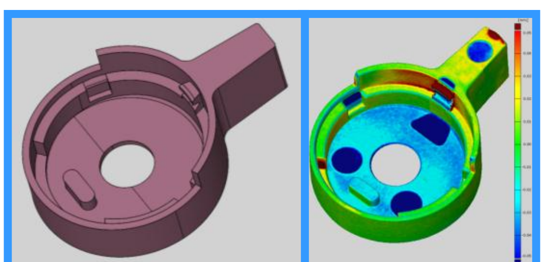
Volume data → Measurement

Surface data / STL → Measurement

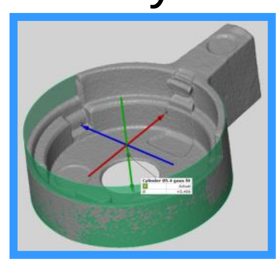
Measurement → Reference data or CAD model

Measurement → Geometry fitting

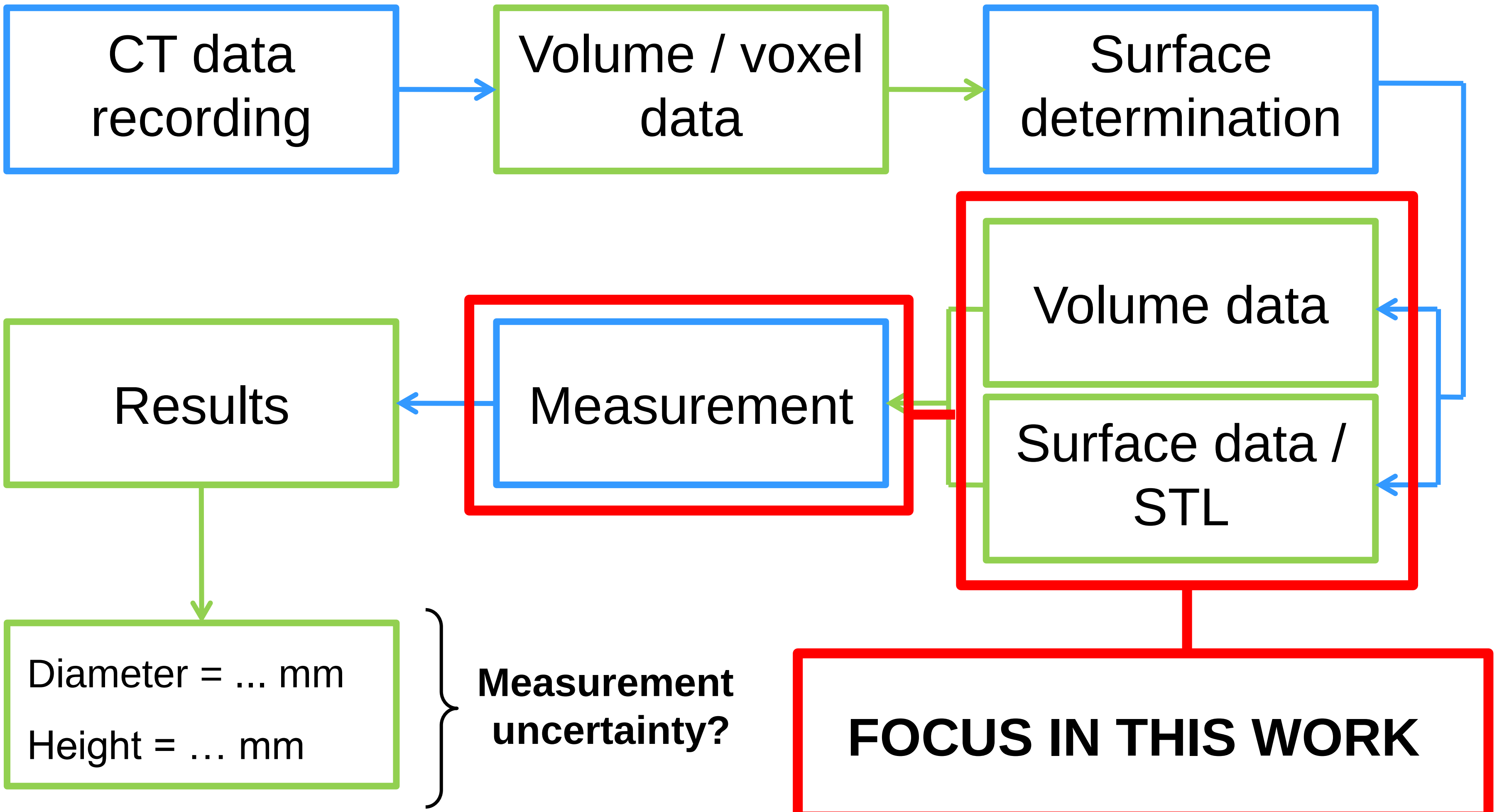
Reference data or CAD model



Geometry fitting



Motivation


CT data recording
Volume / voxel data
Surface determination
Volume data
Surface data / STL
Measurement
Results
Diameter = ... mm
Height = … mm
Measurement uncertainty?
FOCUS IN THIS WORK

Objectives

The objective was to perform geometrical measurements on selected industrial parts using a micro CT system

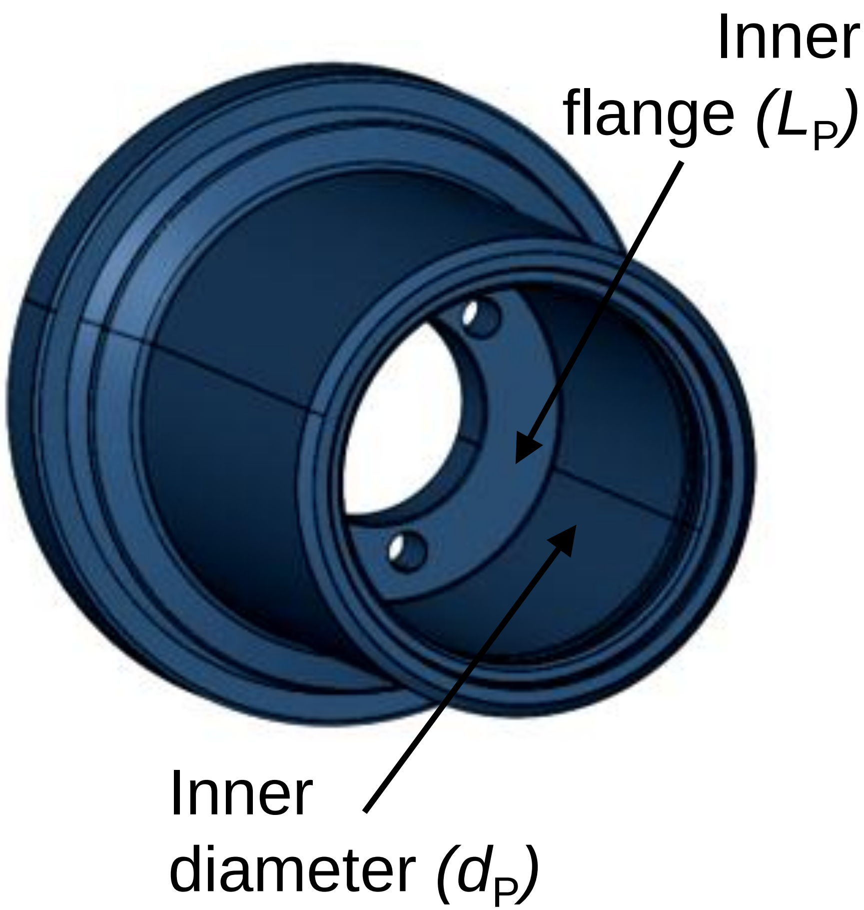
The specific aims are:

- The comparison of available evaluation software for 3D-CT inspection with respect to data representation and measuring strategies.
- The calculation of the measurement uncertainty as the quality parameter of the measurements.

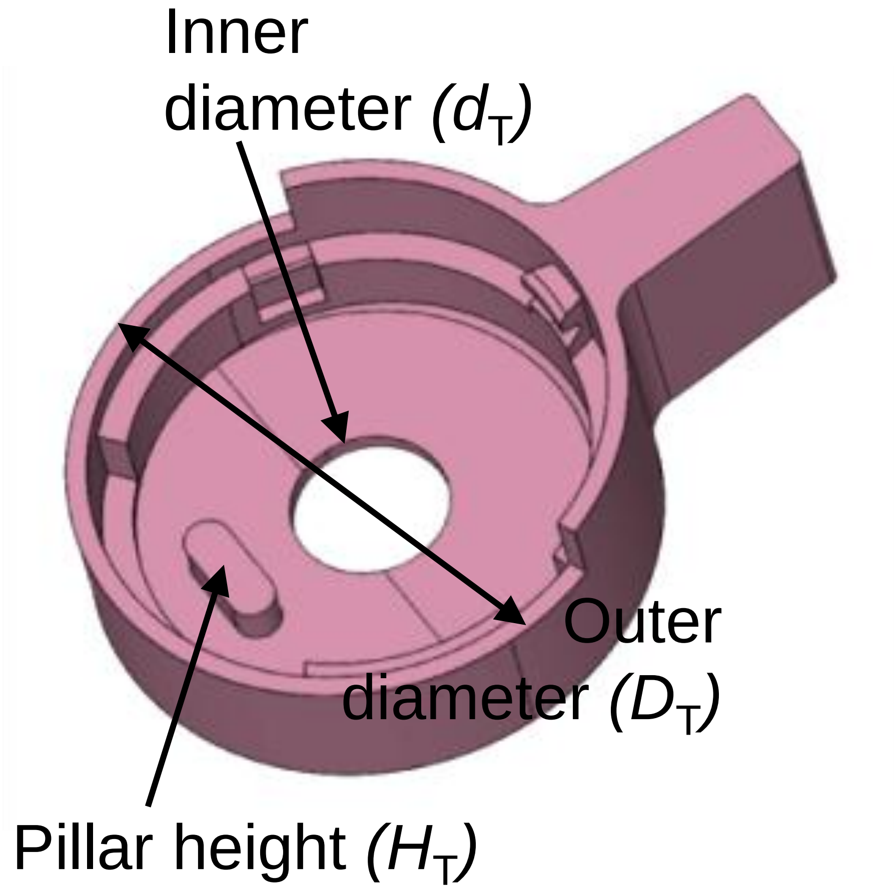
Software	Software producer	Measurement performed on
Calypso CT 4.8.10.16	Zeiss	Volume data
VGStudio MAX 2.1	Volume Graphics	Volume data
ATOS Professional V7 SR2	GOM Inspect	Polygonal mesh

Case study description

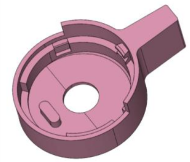
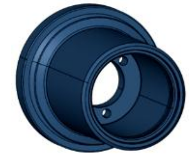
PIPE CONNECTOR



TOGGLE



Measuring setup for tactile, optical and CT measurements


Tactile CMM
OMC 850, ZEISS

MPE_{TCMM} = (2.5+L/300) µm in x, y, z

Optical CMM
DeMeet 220, DeMeet

MPE_{OCMM} = (4+L/150) µm in x, y and 3.5 µm in z

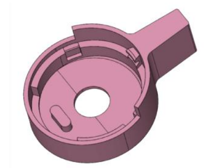
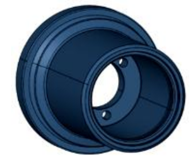
REFERENCE MEASUREMENTS

CT scanner
Metrotom 1500, ZEISS

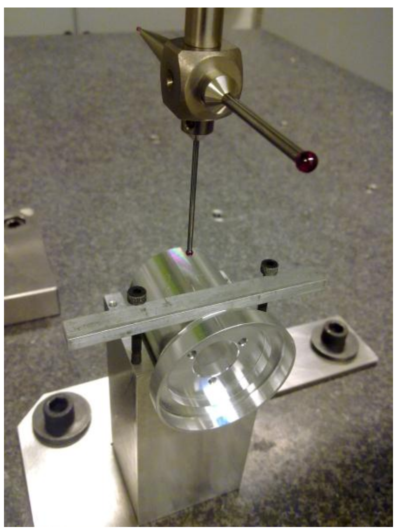
MPE_{CT} = (9+L/50) µm in x, y, z

ACTUAL MEASUREMENTS

Measuring setup for tactile, optical and CT measurements

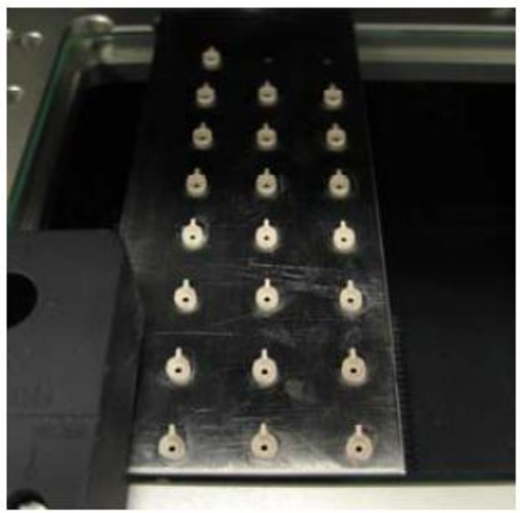





Tactile CMM
OMC 850, ZEISS



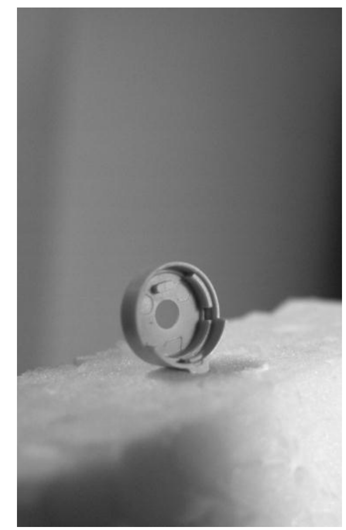
Acquisition of single points

Optical CMM
DeMeet 220, DeMeet



Edge detection and auto-focusing routine

CT scanner
Metrotom 1500, ZEISS

Acquisition of virtual points on reconstructed workpiece

REFERENCE MEASUREMENTS

ACTUAL MEASUREMENTS

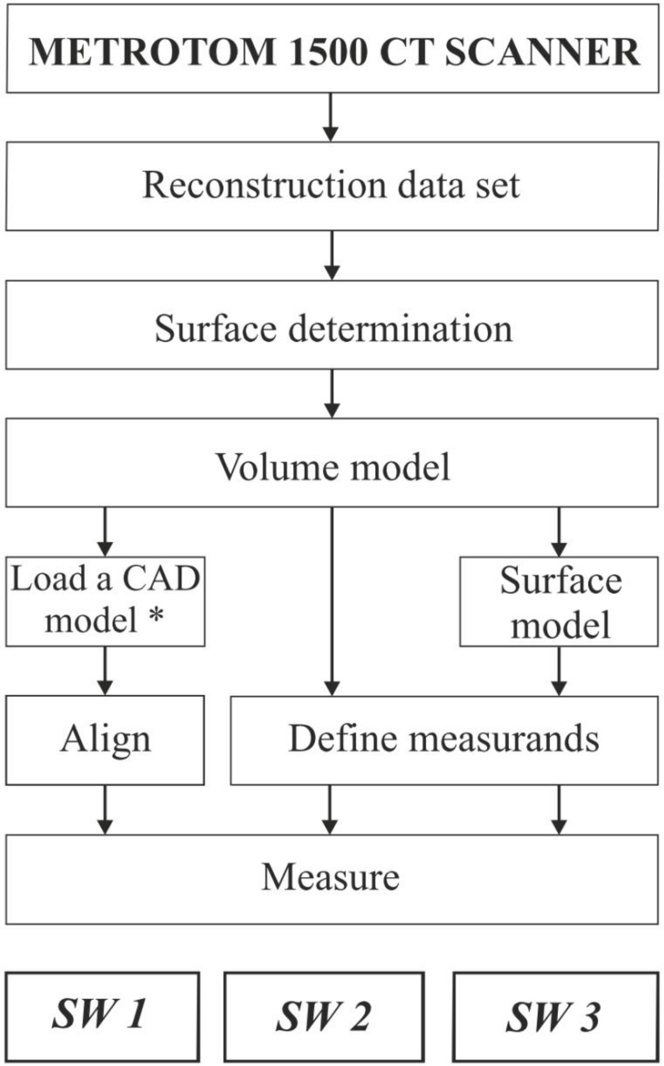
Uncertainty assessment

Measuring uncertainty evaluated according to GUM procedures as:

$$\boxed{U_{CT} = k \cdot \sqrt{u_{ref}^2 + u_p^2 + u_e^2 + b^2}}$$

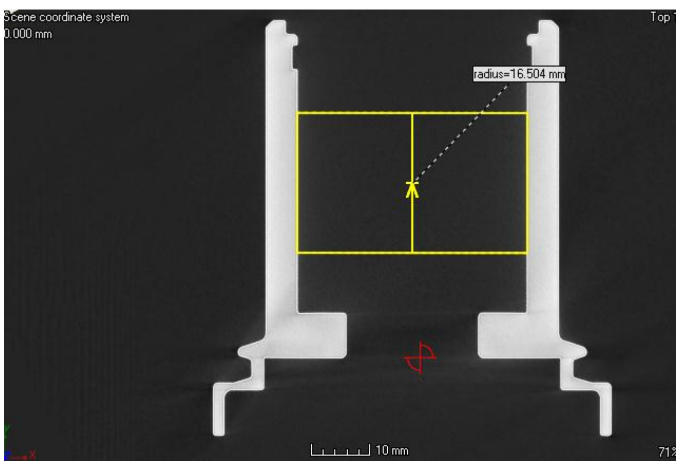
- *k* : coverage factor (*k* = *2* for a confidence interval of 95%);
- u_{ref} : standard uncertainty from reference measurements on tactile and optical CMM, respectively;
- u_p : standard uncertainty of the measuring procedure for each measurand, $u_p = h \cdot (s/\sqrt{n})$ where $n = 3$ and $s = 2.3$;
- u_e : temperature-related standard uncertainty calculated for a deviation of ±0.5 ºC from standard temperature. Coefficient of linear expansion for aluminum: $23 \cdot 10^{-6}$ ºC^{-1} and $49 \cdot 10^{-6}$ ºC^{-1} for LPC;
- *b* : Measurement bias from expected value of reference measurements.

Definition of measuring strategies



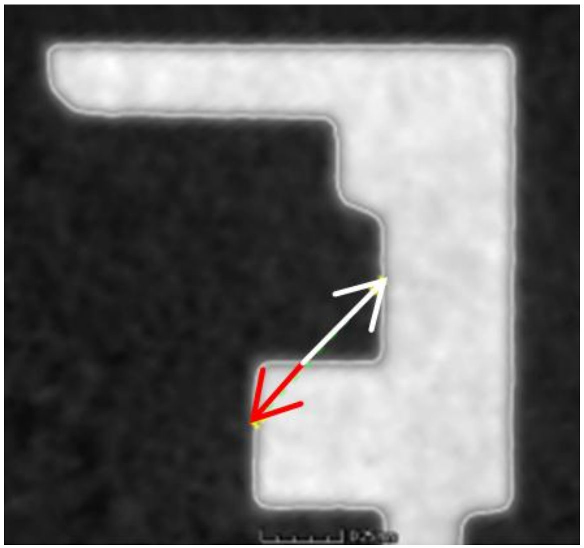
Software tool	Data set	Product
SW1	Voxel model / volume data	Calypso 4.8
SW2	Voxel model / volume data	VGStudio MAX 2.1
SW3	STL model / surface data	ATOS V7

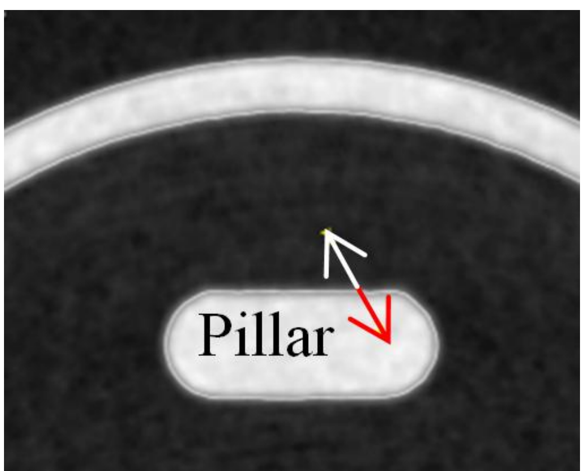
Definition of measuring strategies



Measurand	***SW1***	***SW2***	***SW3***
Diameter (d_P, D_T)	Circle	Circle	Circle
	Spiral	Feature fit	Feature fit
	Recall	Cylinder circle	Cylinder circle
Distance (L_P) and Height (H_T)	Plane-Plane	Plane-Plane	Plane-Plane
	Point-Plane	Point-Plane	Point-Plane

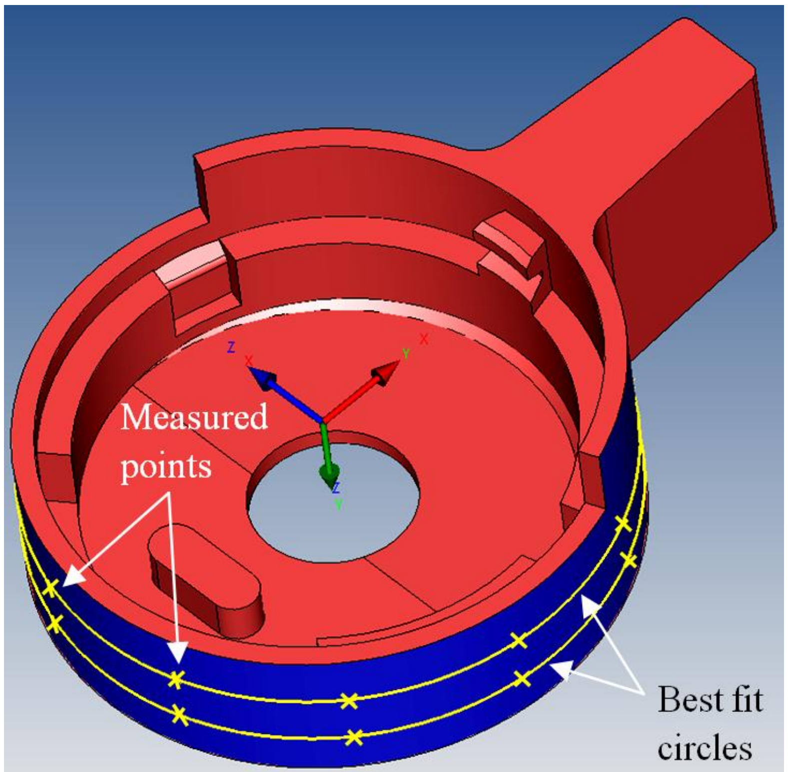
Definition of measuring strategies





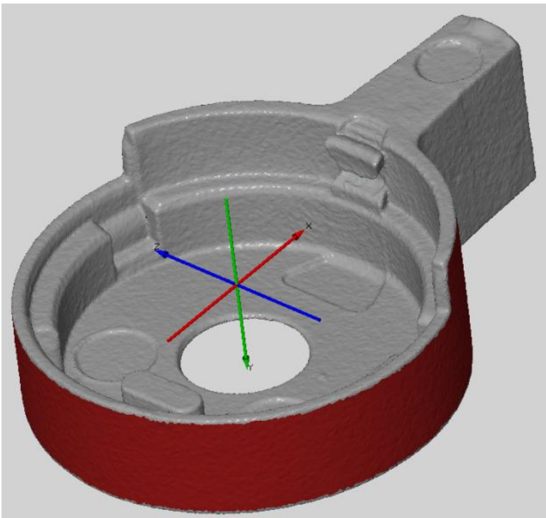
Measurand	*SW1*	*SW2*	*SW3*
Diameter (d_P, D_T)	Circle	Circle	Circle
	Spiral	Feature fit	Feature fit
	Recall	Cylinder circle	Cylinder circle
Distance (L_P) and Height (H_T)	Plane-Plane	Plane-Plane	Plane-Plane
	Point-Plane	Point-Plane	Point-Plane
Angle (α_P)	Circle	Circle	Circle
		Cylinder	Cylinder

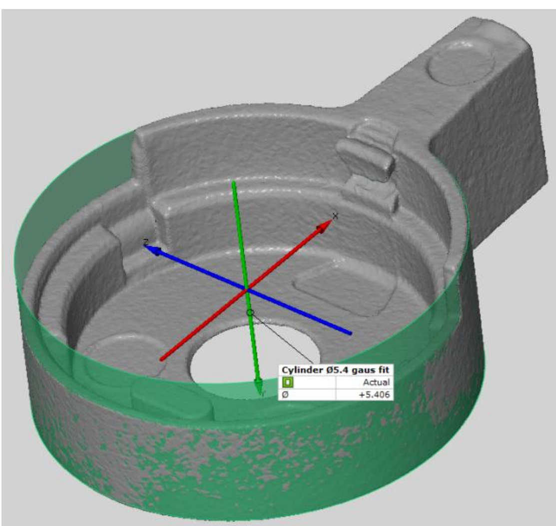
Definition of measuring strategies



Measurand	*SW1*	*SW2*	*SW3*
Diameter (d_P, D_T)	Circle	Circle	Circle
	Spiral	Feature fit	Feature fit
	Recall	Cylinder circle	Cylinder circle
Distance (L_P) and Height (H_T)	Plane-Plane	Plane-Plane	Plane-Plane
	Point-Plane	Point-Plane	Point-Plane

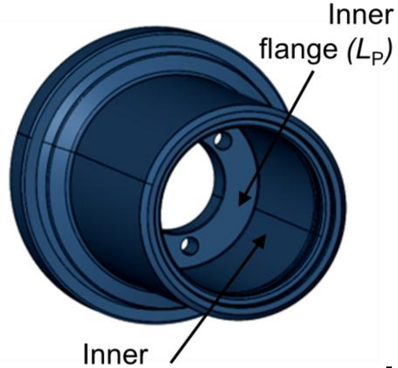
Definition of measuring strategies





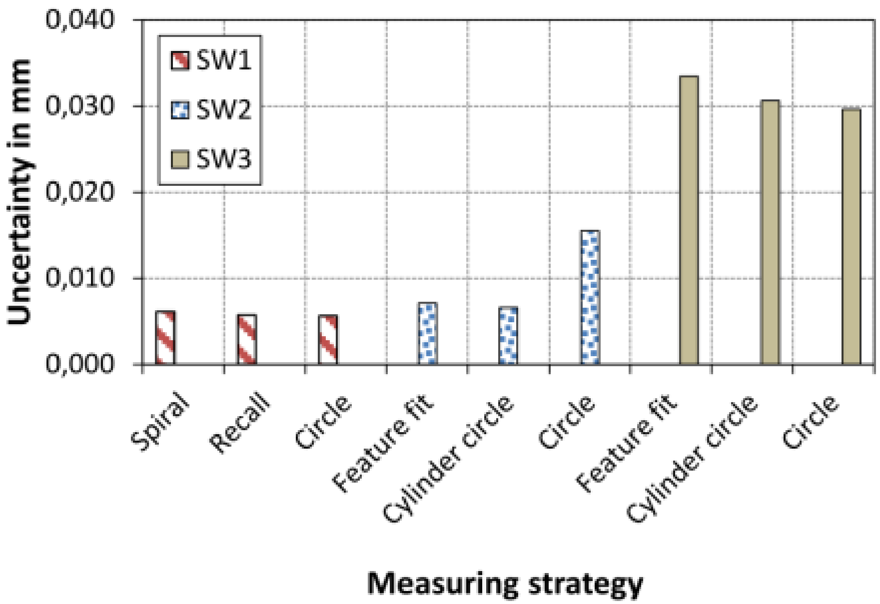
Measurand	***SW1***	***SW2***	***SW3***
Diameter (d_P, D_T)	Circle	Circle	Circle
	Spiral	Feature fit	Feature fit
	Recall	Cylinder circle	Cylinder circle
Distance (L_P) and Height (H_T)	Plane-Plane	Plane-Plane	Plane-Plane
	Point-Plane	Point-Plane	Point-Plane

Results: Pipe connector

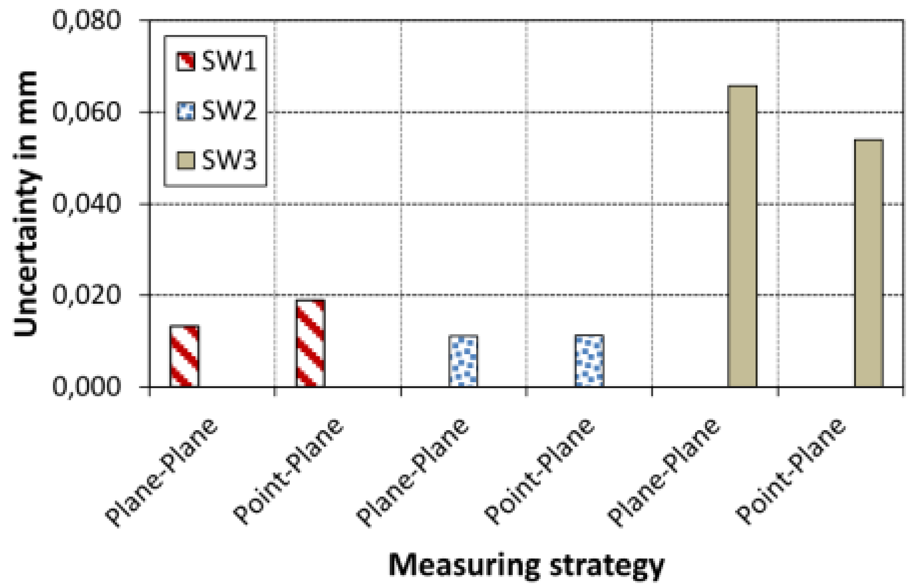


Voxel size: 108 µm

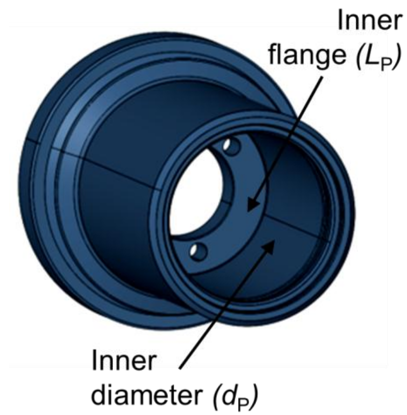
Diameter: d_P = 33 mm



Distance: L_P = 6.4 mm

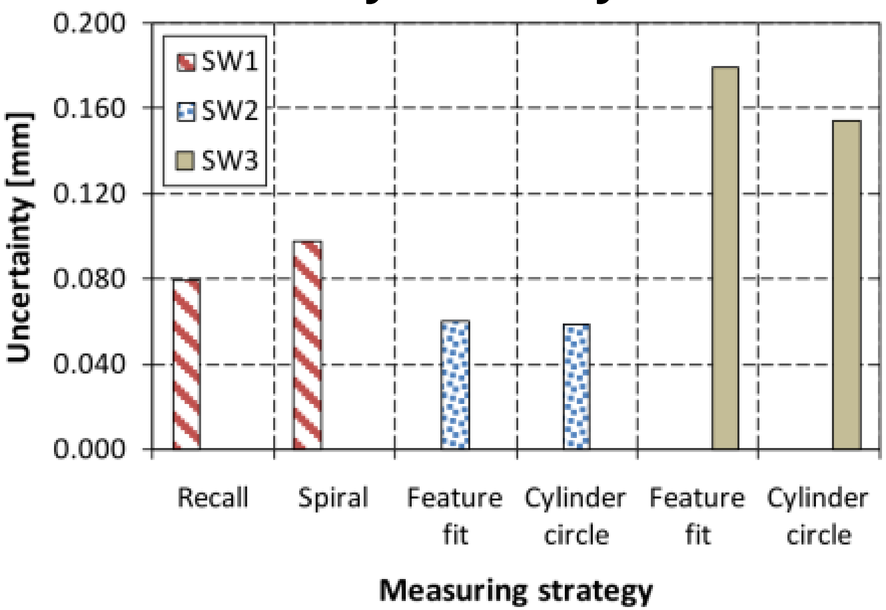


Results: Pipe connector

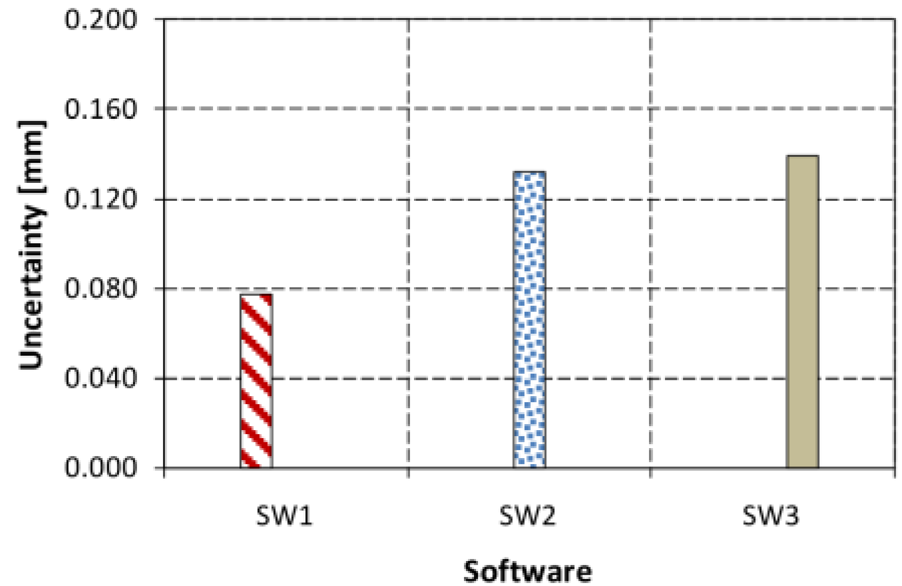


Voxel size: 108 µm

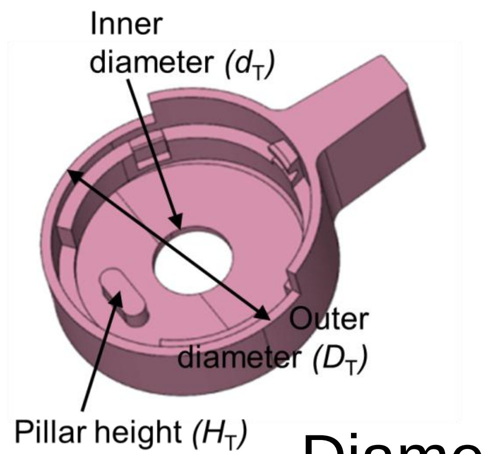
Cylindricity



Parallelism

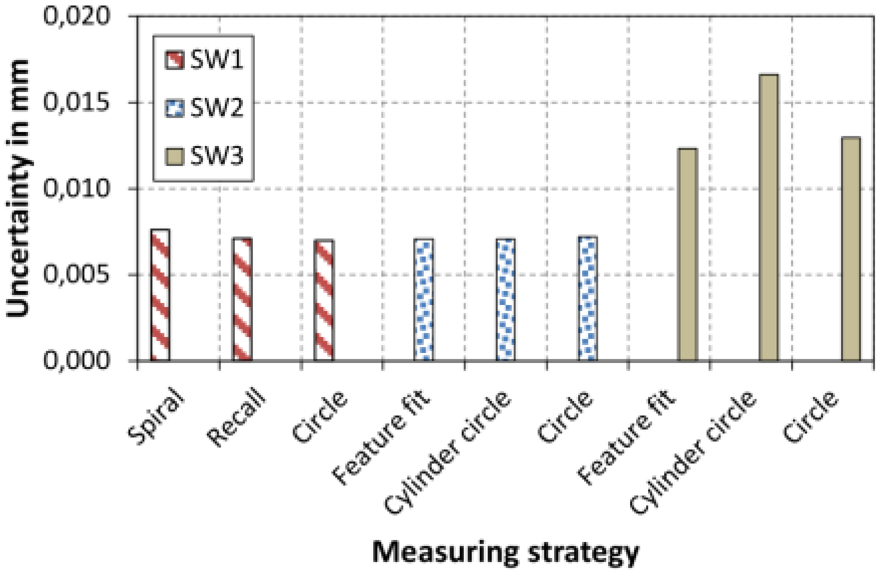


Results: Toggle

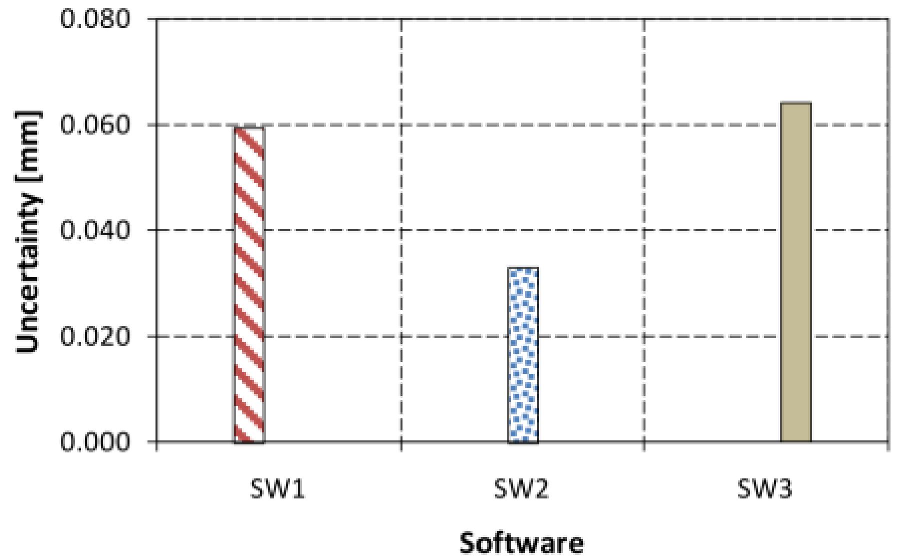


Voxel size: 19 µm

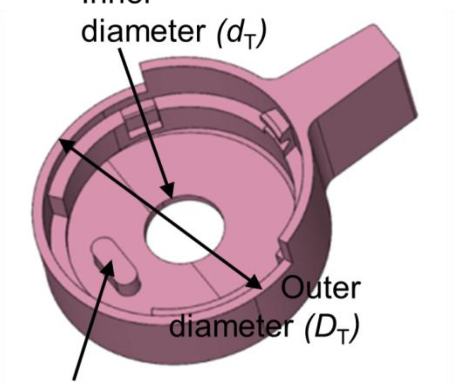
Diameter: D_T = 5.4 mm



Diameter: d_T = 1.55 mm

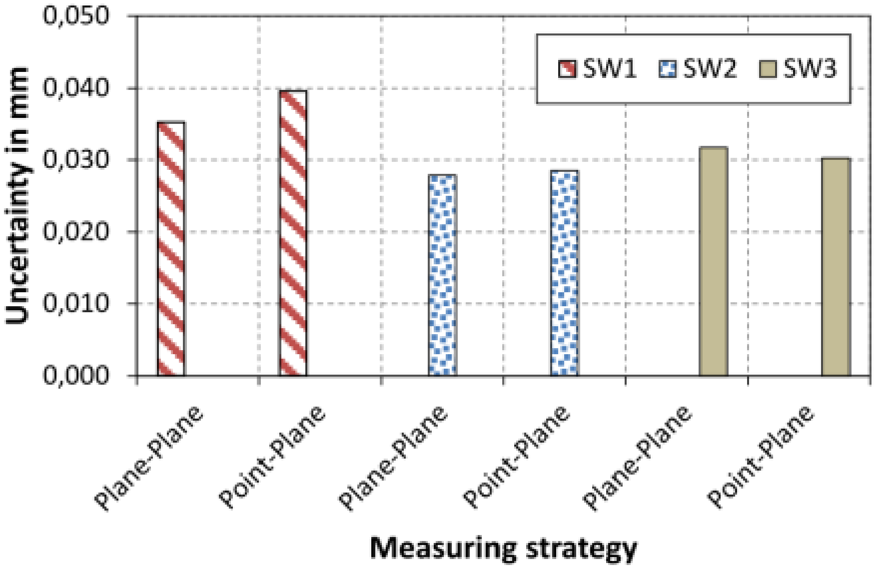


Results: Toggle

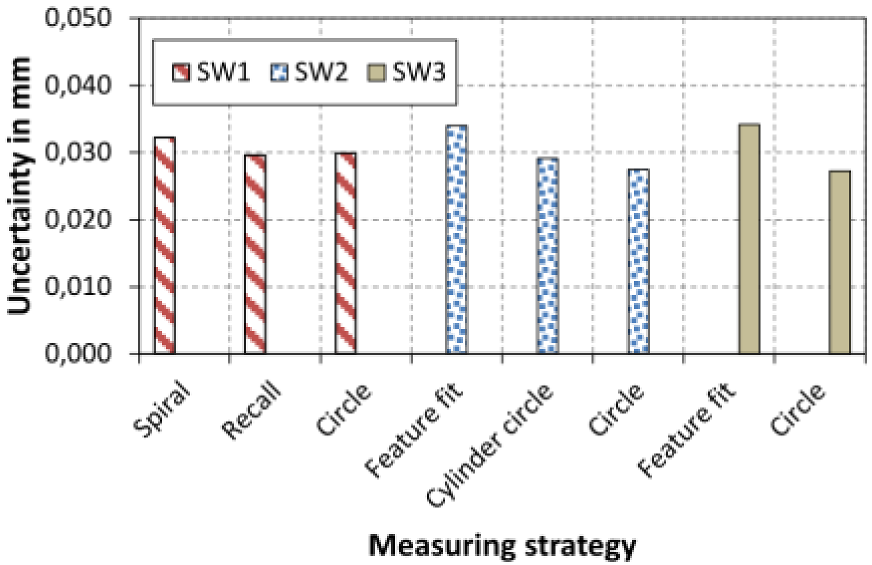


Voxel size: 19 µm

Height: $H_T = 0.38$ mm



Concentricity



Conclusions

- Different measuring strategies were applied using 2 different CT data representations in 3 commercial inspection software tools to document its influence on selected measurands by the assessment of the measurement uncertainties.

- To estimate the task-specific measurement uncertainties the experimental method was used.

- Two industrial parts were used: a pipe connector and a toggle.

Conclusions

- Pipe connector (voxel size: 108 µm):
  - Using STL data in ATOS (SW3) the uncertainties for diameter, cylindricity, and distance measurements are significantly higher in contrast to uncertainties obtained using Calypso (SW1) and VG (SW2)
- Toggle (voxel size: 19 µm):
  - For the outer diameter D_T the uncertainties are significantly higher in contrast to uncertainties obtained using Calypso (SW1) and VG (SW2)
- The main contributor is the measurement bias ***b***

Conclusions

What can we say in general?

There are measuring strategies where the measurement uncertainty is twice as high compared to others!

<u>Good practice:</u>

Testing of different strategies in order to perform a relative comparison of the result of the measurements

+

Using traceable reference data for uncertainty estimations

THANK YOU FOR YOUR ATTENTION